BATTERIES – JUST THE FACTS
Wet Cell, Gel Cell and AGM

BY BOB THOMAS

At the 2016 ERA show, there was some conversation about batteries during an open forum. Specifically, it was suggested that AGM (absorbed glass mat) batteries were to blame for a large number of stator failures on 200 amp Denso hairpin alternators on a fleet of Ford diesel pickups. After talking to a production rebuilder who was present at the discussion, he stated that stator failures are extremely common on these trucks using conventional flooded batteries too. The debate seemed to peak interest. But the basis for the original claim was never fully explained.

Here, we will simply attempt to outline the differences between conventional lead-acid wet cell batteries and the alternatives, including AGM's. Hopefully this will help to help you better serve your customers in choosing the battery best suited to fit their needs.

The lead-acid battery was invented over 150 years ago, but it did not gain wide spread use until the 1900's when the mass production of automobiles created a rapidly growing demand for it. While many other battery chemistries have been developed since then, none so far have been able surpass the lead-acid in terms of cost and performance when it comes to cranking engines of all types.

Any battery, no matter what type, is simply a storage device to provide electrical energy when needed. All batteries store chemical energy that can be quickly converted into electrical energy. All batteries share three parts in common: an anode (negative), a cathode (positive) and an electrolyte. The electrolyte stores the energy. The anode and cathode are the electrical connections used to access the energy in the electrolyte. Storage batteries like the lead-acid can be recharged.

In the case of lead-acid batteries, the anode and cathode are grid-structured plates made primarily of lead. Depending upon intended use of the battery, metals such as antimony, calcium, tin, nickel or selenium may be used to add strength and improve characteristics. The electrolyte is sulfuric acid diluted with purified water to a density of about 1.25 kg/L (kilogram per liter) or a little over 30% acid in a lead-acid wet cell.

As the battery discharges, the sulfuric acid is converted to sulfur which deposits on the plates and water that dilutes the electrolyte. Recharging will recombine the deposited sulfur with hydrogen and oxygen in the water to increase the acid concentration back to the 30% level. The charging process creates extra hydrogen as a byproduct that must be vented off. The gassing also causes the gradual loss of water.

Every cell in a lead-acid battery contains a group of plates, half being anodes and half being cathodes. The negative anodes are all connected together in parallel and the positive cathodes are connected in the same way. Each cell is actually a stand alone battery, with one anode connection and one cathode connection. It is capable of providing approximately 2.1 volts when fully charged (30% acid). When connected in series with five other cells, the whole 12 volt battery can supply about 12.6 volts.

Today, there are three designs based on the original lead-acid wet cell principle. They are the wet cell, the gel cell and the absorbed glass mat (AGM). While they all function basically the same way, each has its own advantages and disadvantages.

Wet Cell

Flooded lead-acid batteries have improved tremendously since their humble beginnings (*see Figure 1*). The batteries used in automobiles in the early part of the 20th century were constructed in tar-coated wood containers that slowly seeped acid. Thin lead sheets were used as plates, separated by wood strips to prevent shorting. Charging systems of the day were not kind to them either, with little or no voltage control. As such they were often overcharged. Used daily on unpaved roads, it was rare for them to last over a year.

Today, battery cases are much more durable, manufactured with polyethylene, polypropylene and carbonized plastics. The plates are grid-shaped lead alloy to increase strength and efficiency. Polyethylene separators, unaffected by the acid, prevent the plates from shorting.

All of this has improved the wet cell's durability and performance. Conventional wet cells are still the least expensive automotive battery to manufacture and the most common in use today. But other options have entered the market and they are gaining acceptance by manufacturers. The major downside of the wet-cell is in the liquid electrolyte itself, which gasses explosive hydrogen, requires the periodic addition of distilled water and is highly corrosive if it leaks or spills over. The caps used today are designed to trap the gases to minimize water loss.

Figure 1 – This is a Delco cranking battery from the 1950's (left) compared to an East Penn made flooded wet cell cranking battery of today (right).

Figure 2 – These gel cell batteries were made for emergency backup service.

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Gel Cell

The gel cell battery was developed primarily to limit water loss during charging by sealing it to prevent gas from escaping. The battery's case is manufactured to withstand some pressure (2 to 3 psi). A gas diffuser is built into the cover to trap vented hydrogen for safer dispersal. A relief valve prevents pressure from exceeding a safe limit. The technology of venting through a pressure valve is referred to as a valve-regulated lead acid (VRLA).

Calcium is added to the grid plates of a gel cell to increase tensile strength and reduce gassing. The electrolyte in gel batteries is mixed with silica to form a jelly-like mass that does not give up gas as easily as the flooded wet cell. This also makes the battery nearly spill proof. While it is often referred to as being "sealed and maintenance free", it is vented and not actually sealed. However, it is designed to never need water and the gel virtually eliminates any leaking.

For those reasons, Gel batteries are used more in emergency back-up systems, lighting and telephone stand-by systems. They usually have a better amp hour (ah) rating than the same size flooded battery (*see Figure 3*).

While the basic chemistry of the gel cell is lead-acid, the addition of calcium and silica change more than the battery's ability to prevent water loss. It also limits charging voltage. Charging will be explained in more detail later. Suffice to say at this point that gel cell batteries can be quickly damaged by what you might consider a safe charging voltage. Also worth mentioning is that VRLA technology is being used in many flooded wet cell batteries today, so a sealed top with a vent does not necessarily mean that the battery is a gel cell.

AGM

The absorbed glass mat battery appeared in the 1980's as a sealed, valve regulated battery that was first used in military aircraft. Reinforced cases permit higher internal pressures than other VRLA batteries – as high as 40 psi in some applications. Unlike a gel cell, the electrolyte is a liquid, suspended in a very fine glass fiber mat. The glass, being non-porous, cannot absorb the electrolyte, but the mat does absorb and hold the liquid between the tiny glass fibers.

The electrolyte can move freely within the mat and maintain uninhibited contact with the plates. The mat holds the electrolyte and serves as the perfect separator between the plates because glass is a very good insulator. Electrons can flow easily through the electrolyte, around the glass fibers.

The plates and saturated mat are compacted prior to case insertion. This is possible because the insulation property of the glass allows much closer plate spacing than other batteries while still preventing the plates from shorting. AGM batteries have been tested by shaking in a commercial paint shaker. No other wet cell design has ever passed this test. AGMs are both very efficient and extremely rugged. They make an excellent choice for off road equipment – small or large (*see Figure 4*).

The leading advantage of an AGM is its very low resistance, which allows it to supply more amperage at a higher voltage than any other lead acid design of the same size and weight. This ability to maintain higher voltage under heavy load makes it excellent for cranking an engine. It also offers a much greater depth-of-discharge than any other cranking battery. That means it can handle deep cycling and the parasitic drains of modern vehicles for longer periods of time. Unlike the flooded wet cell and gel cell, the AGM can accept higher amounts of amperage during recharging because of its low resistance. That allows it to be recharged up to five times faster.

The downsides are high cost, a sensitivity to overcharging and susceptibility to damage by high temperatures. In spite of that, some high end automotive applications are being delivered to customers today with AGM batteries as standard equipment. Most if not all are located away from the engine compartment. Those vehicles' charging systems are also programmed specifically for the characteristics of the AGM battery.

Charging Lead-Acid Batteries

Prior to charging, always test the battery for state of charge to know where you stand. When you are reading voltage of a battery that has recently been on a charger, your reading will be skewed by a "surface" charge. That is a temporarily higher voltage than the battery's actual state would indicate. A surface charge can be "knocked off" by applying a brief heavy load for a second or two. Do not be fooled into thinking that a battery is fully charged as soon as you see 12.7 volts. Surface charges will eventually dissipate on their own once the charging stops.

State of Charge	Specific Gravity	12V	6V
100%	1.265	12.7	6.3
75%	1.225	12.4	6.2
50%	1.190	12.2	6.1
25%	1.155	12.0	6.0
Discharged	1.120	11.9	6.0
Shorted Cell	1.265	10	4

Each type of lead-acid battery has a different absorption rate. This refers to the maximum rate at which it can be charged, affected by the charge voltage. For that reason, absorption rate must be considered when swapping battery type on a vehicle or whenever recharging a battery.

Whenever you are recharging a deeply discharged battery, no matter whether it is a cranking or deep cycle battery, the charging process must go through three stages. They are **bulk** or constant current, **absorption** or topping and **float**. Recommended voltages for each stage vary by battery type and manufacture. The numbers provided here are intended as a general guide.

Bulk may also be called the constant current or boost stage. During this stage of charging the battery is brought up to a level of 70% to 80% of full charge.

- Wet Cell 14.6v to 15.2v
- AGM 14.6v to 15.0v
- Gel Cell 14.1v to 14.5v

Batteries that are only partially discharged, may not need bulk charging. Internal resistance is high, so higher voltage is needed. Monitor voltage and battery temperature when charging. Reduce the rate of charge if the temperature exceeds 120°F.

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Figure 3 – Note that this flooded wet cell battery has the vent on the side of the cover.

Figure 4 – These deep cycle AGM deep batteries were made by East Penn.

Absorption may also be called the topping off stage. During absorption the battery is brought up to 95% to 98% charge.

- Wet Cell 14.2v to 14.7v
- AGM 14.2v to 14.5v
- Gel Cell 14.0v to 14.2v

As internal resistance decreases, charging voltage must be decreased. However, a battery's own voltage capacity increases with the state of charge, and that causes the battery to become increasingly resistant to accepting a charge. For that reason, the absorption stage normally takes longer than the bulk stage. Reduce charge rate if temperature exceeds 120°F.

Float stage will bring the battery up to 100% charge with a further reduction of charge rate.

- Wet Cell 13.1v to 13.4v
- AGM 13.2v to 13.4v
- Gel Cell 13.1v to 13.3v

Batteries should not be left in float for extended periods. Most serviceable automotive batteries require one to two hours at most.

Be aware that much of the above charging information pertains to recharging a discharged battery. Under normal circumstances, that should never happen to a cranking battery unless the vehicle has been driven with an non-working alternator or has had it's lights left on overnight. Normally, if all is well, a cranking battery should be in a high state of charge when the a vehicle is shut down. Even after a week of sitting unused, a good battery should remain in a high state of charge. When it is called upon to crank the engine again, it will give up some of that energy. But the amount of that energy is only a small percentage of what the battery actually holds, perhaps 5% at most. The alternator should ideally be capable of replacing that quickly.

Lithium-Ion

I am mentioning lithium-ion batteries here only because some are beginning to be marketed in automotive group sizes by at least one manufacturer. Lithium batteries have been around for a long time in many applications ranging from cell phones and lap top computers to power tools and lighting. They excel in those applications. They are light weight, charge quickly, long-lasting and environmentally friendly. But will they work in vehicles?

Lithium batteries are already being used in electric and hybrid battery packs. Someday, we may see them in automotive applications in place of the 100-year-old lead-acid cranking battery. However, there are a number of obstacles to overcome that include high cost and charge voltage requirements that do not match today's vehicle's charging system.

To retro-fit the lithium-ion battery into a current vehicle requires an electronic circuit (built into the lithium-ion battery pack) that reduces the vehicle's charge voltage to match the lithium-ion battery pack's requirements. If the battery is used as intended – to crank the engine, it should do that very well. Once the alternator takes over, all accessories should perform normally on charging system voltage. The unanswered question is: Is it really worth the cost?

Conclusion

Consumers have many options when it comes to buying a battery today. When a customer comes to you to purchase a battery for their vehicle, that person is seeking your advice. To aid him or her in making the best decision, you need to know and understand exactly how the battery will be used. Will it be used daily? Are the trips short or long? Will it sit unused for weeks or months at a time?

What was in the vehicle originally is becoming increasingly important as modern charging systems are often designed to recharge and maintain one battery chemistry better than the others. It is true that just about any 12 volt replacement battery that will fit in the battery box will probably crank the engine. But it may not last as long as your customer expects it to.

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